General Specifications

Item	Specification
Lubricants and Sealants	
SAE 5W-20 Premium Synthetic Blend Motor Oil XO-5W20-QSP	WSS-M2C153-H
Diesel engine oil	Refer to owner literature
Gasoline Engine Oil Dye 164-R3705	ESE-M99C103-B1
Threadlock® 262 E2FZ-19554-B	WSK-M2G351-A6

Engine

NOTE: This section contains information, steps and procedures that may not be specific to your engine.

This section covers general procedures and diagnosis and testing of the engine system, except for exhaust emission control devices, which are covered in the Powertrain Control/Emissions Diagnosis Manual.

The engine incorporates the following features:

- a closed positive crankcase ventilation (PCV) system. For additional information, refer to Section 303-08 .
- an exhaust emission control system. For additional information, refer to Section 303-08 .
- an evaporative emission control system. For additional information, refer to Section 303-13 .

Some engines incorporate a fail-safe cooling system. Refer to the appropriate section in Group 303 for the procedure.

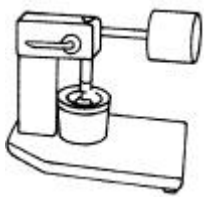
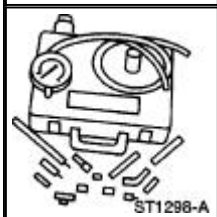
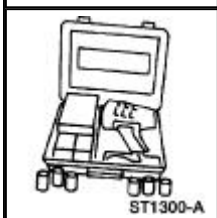
The engine, fuel system, ignition system, emissions system and exhaust system all affect exhaust emission levels and must be maintained according to the maintenance schedule. Refer to the scheduled Maintenance Guide.

Correct engine identification is required to order parts. Refer to the appropriate section in Group 303 for the procedure.

For complete vehicle and engine identification codes, refer to Section 100-01 .

Engine

Special Tool(s)

	Commercially Available Leakdown Tester —
	Quick Disconnect Compression Tester 134-R0212 or equivalent
	Dial Indicator Gauge Adapter 303-007 (TOOL-6565-AB) or equivalent
	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent
	Engine Cylinder Leak Detection/Air Pressurization Kit 014-00708 or equivalent
	Oil Pressure Gauge 303-088 (T73L-6600-A)
	UV Leak Detector Kit 164-R0756 or equivalent
	Vacuum/Pressure Tester 164-R0253 or equivalent

ST1297-A	

Material

Item	Specification
Gasoline Engine Oil Dye 164-R3705 or equivalent	ESE-M99C103-B1
Engine Oil	Refer to owner literature

Inspection and Verification

1. Verify the customer concern by operating the engine to duplicate the condition.
2. Visually inspect for obvious signs of mechanical damage. Refer to the following chart.

Visual Inspection Chart

Mechanical
● Engine coolant leaks ● Engine oil leaks ● Fuel leaks ● Damaged or severely worn parts ● Loose mounting bolts, studs and nuts

3. If the inspection reveals obvious concerns that can be readily identified, repair as necessary.
4. If the concerns remain after the inspection, determine the symptoms. GO to Symptom Chart .

Symptom Chart

Symptom Chart

Condition	Possible Sources	Action
● Difficult starting	● Damaged ignition system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Damaged fuel system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Damaged starting system.	● Refer to the appropriate section in Group 303 for the procedure.

		REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Damaged charging system/battery.	● REFER to Section 414-00 .
	● Burnt valve.	● INSTALL a new valve.
	● Worn piston.	● INSTALL a new piston.
	● Worn piston rings.	● INSTALL new piston rings.
	● Worn cylinder.	● REPAIR or INSTALL a new cylinder block.
	● Damaged head gasket.	● INSTALL a new head gasket.
	● Damaged cooling system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
● Poor idling	● Vacuum leaks.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Malfunctioning or damaged ignition system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Malfunctioning or damaged fuel system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Damaged valve tappet or lash adjuster.	● INSTALL a new valve tappet or lash adjuster.
	● Damaged valve tappet guide or lash adjuster.	● INSTALL a new valve tappet guide or valve tappet.
	● Incorrect valve-to-valve seat contact.	● REPAIR or INSTALL a new valve or valve seat.
	● Damaged head gasket.	● INSTALL a new head gasket.
● Abnormal combustion	● Malfunctioning or damaged fuel system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Malfunctioning or damaged ignition system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	● Malfunctioning or damaged air intake system.	● Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis

		(PC/ED) manual.
	• Damaged valve tappet or lash adjuster.	• INSTALL a new valve tappet or lash adjuster.
	• Damaged valve tappet guide or valve tappet.	• INSTALL a new valve tappet guide or valve tappet.
	• Burnt or sticking valve.	• REPAIR or INSTALL a new valve.
	• Weak or broken valve spring.	• INSTALL a new valve spring.
	• Carbon accumulation in combustion chamber.	• ELIMINATE carbon buildup.
• Excessive oil consumption	• Leaking oil.	• REPAIR oil leakage.
	• Malfunctioning PCV system.	• REPAIR or INSTALL new necessary components.
	• Worn valve stem seal.	• INSTALL a new valve stem seal.
	• Worn valve stem or valve guide.	• INSTALL a new valve and valve guide.
	• Sticking piston rings.	• REPAIR or INSTALL new piston rings.
	• Worn piston ring groove.	• INSTALL a new piston and piston pin.
	• Worn piston or cylinder.	• REPAIR or INSTALL a new piston or cylinder block.
• Engine noise	• Leaking exhaust system.	• REPAIR exhaust leakage.
	• Incorrect drive belt tension.	• REFER to Section 303-05 .
	• Malfunctioning generator bearing.	• Refer to the appropriate section in Group 414 for the procedure.
	• Malfunctioning water pump bearing.	• REFER to Section 303-03A .
	• Malfunctioning or damaged cooling system.	• REFER to Section 303-03A .
	• Malfunctioning or damaged fuel system.	• Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	• Loose timing chain/belt (6268).	• ADJUST or INSTALL a new timing chain/belt.
	• Damaged timing chain tensioner (6L266).	• INSTALL a new timing chain tensioner.
	• Excessive main bearing clearance.	• ADJUST clearance or INSTALL a new crankshaft main bearing (6333).

	• Seized or heat damaged crankshaft main bearing.	• INSTALL a new crankshaft main bearing.
	• Excessive crankshaft end play.	• INSTALL a new thrust bearing or crankshaft (6303).
	• Excessive connecting rod bearing clearance.	• INSTALL a new connecting rod bearing or connecting rod (6200).
	• Heat damaged connecting rod bearing (6211).	• INSTALL a new connecting rod bearing.
	• Damaged connecting rod bushing (6207).	• INSTALL a new connecting rod bushing.
	• Worn cylinder.	• REPAIR or INSTALL a new cylinder block (6010).
	• Worn piston (6108) or piston pin (6135).	• INSTALL a new piston or piston pin.
	• Damaged piston rings.	• INSTALL new piston rings.
	• Bent connecting rod.	• INSTALL a new connecting rod.
	• Malfunctioning valve tappet (6500) or lash adjuster.	• INSTALL a new valve tappet or lash adjuster.
	• Excessive valve tappet or lash adjuster clearance.	• ADJUST clearance or INSTALL a new valve tappet guide or valve tappet.
	• Broken valve spring (6513).	• INSTALL a new valve spring.
	• Excessive valve guide clearance.	• ADJUST clearance or INSTALL a new valve guide (6510) or valve.
• Insufficient power	• Malfunctioning or damaged ignition system.	• Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	• Malfunctioning or damaged fuel system.	• Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	• Malfunctioning or damaged air intake system.	• Refer to the appropriate section in Group 303 for the procedure. REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual.
	• Damaged or plugged exhaust system.	• INSPECT exhaust system.
	• Incorrect tire size.	• REFER to Section 204-04 .
	• Dragging brakes.	• REFER to Section 206-00 .

	• Slipping transmission. • Malfunctioning valve tappet or lash adjuster. • Damaged valve tappet guide or valve tappet. • Compression leakage at valve seat. • Seized valve stem. • Weak or broken valve spring. • Worn or damaged camshaft. • Damaged head gasket (6051). • Cracked or distorted cylinder head. • Damaged, worn or sticking piston ring (s). • Worn or damaged piston.	• Refer to the appropriate section in Group 307 for the procedure. • INSTALL a new valve tappet or lash adjuster. • INSTALL a new valve tappet guide or valve tappet. • REPAIR or INSTALL a new valve, valve seat or cylinder head (6049). • INSTALL a new valve. • INSTALL a new valve spring. • INSTALL a new camshaft. • INSTALL a new head gasket. • INSTALL a new cylinder head. • REPAIR or INSTALL a new piston ring(s). • INSTALL a new piston and piston pin.

Component Tests

Engine Oil Leaks

NOTE: When diagnosing engine oil leaks, the source and location of the leak must be positively identified prior to repair.

Prior to carrying out this procedure, clean all sealing surface areas with a suitable solvent to remove all traces of oil.

Engine Oil Leaks—Fluorescent Oil Additive Method

Use the UV Leak Detector Kit to carry out the following procedure for oil leak diagnosis.

1. Add gasoline engine oil dye. Use a minimum 14.8 ml (0.5 ounce) to a maximum 29.6 ml (1 ounce) of fluorescent additive to all engines. If the oil is not premixed, fluorescent additive must first be added to crankcase.

2. Run the engine for 15 minutes. Stop the engine and inspect all seal and gasket areas for leaks using the UV Leak Detector Kit. A clear bright yellow or orange area will identify the leak. For extremely small leaks, several hours may be required for the leak to appear.

Leakage Points—Underhood

Examine the following areas for oil leakage:

- valve cover gaskets

- intake manifold gaskets
- cylinder head gaskets
- oil bypass filter
- oil filter adapter
- engine front cover
- oil filter adapter and filter body
- oil level indicator tube connection
- oil pressure sensor

Leakage Points—Under Engine—With Vehicle on Hoist

- oil pan gaskets (6710)
- oil pan sealer
- oil pan rear seal (6723)
- engine front cover gasket
- crankshaft front seal (6700)
- crankshaft rear oil seal (6701)
- crankshaft main bearing cap side bolts
- oil filter adapter and filter body
- oil cooler, if equipped

Leakage Points—With Transmission and Flywheel Removed

- crankshaft rear oil seal
- rear main bearing cap parting line
- rear main bearing cap and seals
- flywheel mounting bolt holes (with flywheel [6375] installed)
- camshaft rear bearing covers (6266) or pipe plugs at the end of oil passages

Oil leaks at crimped seams in sheet metal parts and cracks in cast or stamped parts can be detected when using the dye method.

Compression Test—Compression Gauge Check

1. Make sure the oil in the crankcase is of the correct viscosity and at the correct level and that the battery (10655) is correctly charged. Operate the vehicle until the engine is at normal operating temperature. Turn the ignition switch to the OFF position, then remove all the spark plugs (12405).

2. Set the throttle plates in the wide-open position.

3. Install a compression gauge such as the Compression Tester in the No. 1 cylinder.

4. Install an auxiliary starter switch in the starting circuit. With the ignition switch in the OFF position, and using the auxiliary starter switch, crank the engine a minimum of five compression strokes and record the highest reading. Note the approximate number of compression strokes

required to obtain the highest reading.

5. Repeat the test on each cylinder, cranking the engine approximately the same number of compression strokes.

Compression Test—Test Results

The indicated compression pressures are considered within specification if the lowest reading cylinder is at least 75 percent of the highest reading. Refer to the Compression Pressure Limit Chart.

Compression Pressure Limit Chart

Maximum Pressure	Minimum Pressure	Maximum Pressure	Minimum Pressure	Maximum Pressure	Minimum Pressure	Maximum Pressure	Minimum Pressure
924 kPa (134 psi)	696 kPa (101 psi)	1131 kPa (164 psi)	848 kPa (123 psi)	1338 kPa (194 psi)	1000 kPa (146 psi)	1544 kPa (224 psi)	1158 kPa (168 psi)
938 kPa (136 psi)	703 kPa (102 psi)	1145 kPa (166 psi)	855 kPa (124 psi)	1351 kPa (196 psi)	1014 kPa (147 psi)	1558 kPa (226 psi)	1165 kPa (169 psi)
952 kPa (138 psi)	717 kPa (104 psi)	1158 kPa (168 psi)	869 kPa (126 psi)	1365 kPa (198 psi)	1020 kPa (148 psi)	1572 kPa (228 psi)	1179 kPa (171 psi)
965 kPa (140 psi)	724 kPa (106 psi)	1172 kPa (170 psi)	876 kPa (127 psi)	1379 kPa (200 psi)	1034 kPa (150 psi)	1586 kPa (230 psi)	1186 kPa (172 psi)
979 kPa (142 psi)	738 kPa (107 psi)	1186 kPa (172 psi)	889 kPa (129 psi)	1303 kPa (202 psi)	1041 kPa (151 psi)	1600 kPa (232 psi)	1200 kPa (174 psi)
933 kPa (144 psi)	745 kPa (109 psi)	1200 kPa (174 psi)	903 kPa (131 psi)	1407 kPa (204 psi)	1055 kPa (153 psi)	1055 kPa (153 psi)	1207 kPa (175 psi)
1007 kPa (146 psi)	758 kPa (110 psi)	1214 kPa (176 psi)	910 kPa (132 psi)	1420 kPa (206 psi)	1062 kPa (154 psi)	1627 kPa (154 psi)	1220 kPa (177 psi)
1020 kPa (148 psi)	765 kPa (111 psi)	1227 kPa (178 psi)	917 kPa (133 psi)	1434 kPa (208 psi)	1075 kPa (156 psi)	1641 kPa (238 psi)	1227 kPa (178 psi)
1034 kPa (150 psi)	779 kPa (113 psi)	1241 kPa (180 psi)	931 kPa (135 psi)	1448 kPa (210 psi)	1083 kPa (157 psi)	1655 kPa (240 psi)	1241 kPa (180 psi)
1048 kPa (152 psi)	786 kPa (114 psi)	1255 kPa (182 psi)	936 kPa (136 psi)	1462 kPa (212 psi)	1089 kPa (158 psi)	1669 kPa (242 psi)	1248 kPa (181 psi)
1062 kPa (154 psi)	793 kPa (115 psi)	1269 kPa (184 psi)	952 kPa (138 psi)	1476 kPa (214 psi)	1103 kPa (160 psi)	1682 kPa (244 psi)	1262 kPa (183 psi)
1076 kPa (156 psi)	807 kPa (117 psi)	1282 kPa (186 psi)	965 kPa (140 psi)	1489 kPa (216 psi)	1117 kPa (162 psi)	1696 kPa (246 psi)	1269 kPa (184 psi)
1089 kPa (158 psi)	814 kPa (118 psi)	1296 kPa (188 psi)	972 kPa (141 psi)	1503 kPa (218 psi)	1124 kPa (163 psi)	1710 kPa (248 psi)	1202 kPa (186 psi)
1103 kPa (160 psi)	827 kPa (120 psi)	1310 kPa (190 psi)	979 kPa (142 psi)	1517 kPa (220 psi)	1138 kPa (165 psi)	1724 kPa (250 psi)	1289 kPa (187 psi)
1110 kPa (161 psi)	834 kPa (121 psi)	1324 kPa (192 psi)	993 kPa (144 psi)	1631 kPa (222 psi)	1145 kPa (166 psi)	—	—

If one or more cylinders reads low, squirt approximately one tablespoon of engine oil on top of the pistons in the low-reading cylinders. Repeat the compression pressure check on these cylinders.

Compression Test—Interpreting Compression Readings

1. If compression improves considerably, piston rings are faulty.

2. If compression does not improve, valves are sticking or seating incorrectly.

3. If two adjacent cylinders indicate low compression pressures and squirting oil on each piston does not increase compression, the head gasket may be leaking between cylinders. Engine oil or coolant in cylinders could result from this condition.
   Use the Compression Pressure Limit Chart when checking cylinder compression so that the lowest reading is within 75 percent of the highest reading.

Cylinder Leakage Detection

When a cylinder produces a low reading, use of the Engine Cylinder Leak Detection/Air Pressurization Kit will be helpful in pinpointing the exact cause.

The leakage detector is inserted in the spark plug hole, the piston is brought up to dead center on the compression stroke, and compressed air is admitted.

Once the combustion chamber is pressurized, a special gauge included in the kit will read the percentage of leakage. Leakage exceeding 20 percent is excessive.

While the air pressure is retained in the cylinder, listen for the hiss of escaping air. A leak at the intake valve (6507) will be heard in the throttle body (9E926). A leak at the exhaust valve (6505) can be heard at the tail pipe. Leakage past the piston rings will be audible at the positive crankcase ventilation (PCV) connection. If air is passing through a blown head gasket to an adjacent cylinder, the noise will be evident at the spark plug hole of the cylinder into which the air is leaking. Cracks in the cylinder block or gasket leakage into the cooling system may be detected by a stream of bubbles in the radiator (8005).

Oil Consumption Test

The following diagnostic procedure is used to determine the source of excessive internal oil consumption.

1. **NOTE:** Oil use is normally greater during the first 16,100 km (10,000 miles) of service. As mileage increases, oil use generally decreases. Vehicles in normal service should get at least 1,450 km per liter (900 miles per quart) after 16,000 km (10,000 miles) of service. High speed driving, towing, high ambient temperature and other factors may result in greater oil use.

   Define excessive oil consumption, such as the number of miles driven per liter (quart) of oil used. Also determine customer's driving habits, such as sustained high speed operation, towing, extended idle and other considerations.

2. Verify that the engine has no external oil leak as described under Engine Oil Leaks in the Diagnosis and Testing portion of this section.

3. Verify that the engine has the correct oil level dipstick (6750).

4. Verify that the engine is not being run in an overfilled condition. Check the oil level at least five minutes after a hot shutdown with the vehicle parked on a level surface. In no case should the level be above MAX or the letter F in FULL. If significantly overfilled, carry out Steps 6a through 6d.

5. Verify the spark plugs are not oil saturated. If the spark plugs are oil saturated and compression is good it can be assumed the valve seals or valve guides are at fault.

6. Carry out an oil consumption test:

a. Drain the engine oil, remove the oil bypass filter (6714) and refill with one liter (quart) less than the recommended amount.
b. Run the engine for three minutes (10 minutes if cold), and allow the oil to drain back for at least five minutes with the vehicle on a level surface.
c. Remove oil level dipstick and wipe clean. (Do not wipe with anything contaminated with silicone compounds.) Reinstall the oil level dipstick, being sure to seat it firmly in the oil level indicator tube (6754). Remove the oil level dipstick and draw a mark on the back (unmarked) surface at the indicated oil level. This level should be about the same as the MIN or ADD mark on the face of the oil level dipstick.
d. Add one liter (quart) of oil. Restart the engine and allow to idle for at least two minutes. Shut off the engine and allow the oil to drain back for at least five minutes. Mark the oil level dipstick, using the procedure above.
e. Record the vehicle mileage.
f. Instruct the customer to drive the vehicle as usual and perform the following:
    - Check the oil level regularly at intervals of 160 to 240 km (100-150 miles).
    - Return to the service point when the oil level drops below the lower (MIN or ADD) mark on the oil level dipstick.
    - Add only full liters (quarts) of the same oil in an emergency. Note the mileage at which the oil is added.
g. Check the oil level under the same conditions and at the same location as in Steps 6c and 6d.
    - Measure the distance from the oil level to the UPPER mark on the oil level dipstick and record.
    - Measure the distance between the two scribe marks and record.
    - Divide the first measurement by the second.
    - Divide the distance driven during the oil test by the result. This quantity is the approximate oil consumption rate in kilometers per liter or in miles per quart.
h. If the oil consumption rate is unacceptable, go to Step 7.

7. Check the positive crankcase ventilation (PCV) system. Make sure the system is not plugged.

8. Check for plugged oil drain-back holes in the cylinder heads and cylinder block.

9. If the condition still exists after performing the above steps, go to Step 10.

10. Perform a cylinder compression test or perform a cylinder leak detection test with Engine Cylinder Leak Detection/Air Pressurization Kit. This can help determine the source of oil consumption such as valves, piston rings or other areas.

11. **NOTE:** After determining if new parts should be installed, make sure correct parts are used.

    Check valve guides for excessive guide clearance. Install new all valve stem seals (6571) after verifying valve guide clearance.

12. Worn or damaged internal engine components can cause excessive oil consumption. Small deposits of oil on the tips of spark plugs can be a clue to internal oil consumption. If internal oil consumption still persists, proceed as follows:

a. Remove the engine from the vehicle and place it on an engine work stand. Remove the intake manifolds (9424), cylinder heads, oil pan (6675) and oil pump (6600).
b. Check piston ring clearance, ring gap and ring orientation. Repair as necessary.
c. Check for excessive bearing clearance. Repair as necessary.

13. Repeat the oil consumption test (Step 6) to confirm the oil consumption concern has been resolved.

Intake Manifold Vacuum Test

Bring the engine to normal operating temperature. Connect the Vacuum/Pressure Tester to the intake manifold. Run the engine at the specified idle speed.

The vacuum gauge should read between 51-74 kPa (15-22 in-Hg) depending upon the engine condition and the altitude at which the test is performed. Subtract 4.0193 kPa (1 in-Hg) from the specified reading for every 304.8 m (1,000 feet) of elevation above sea level.

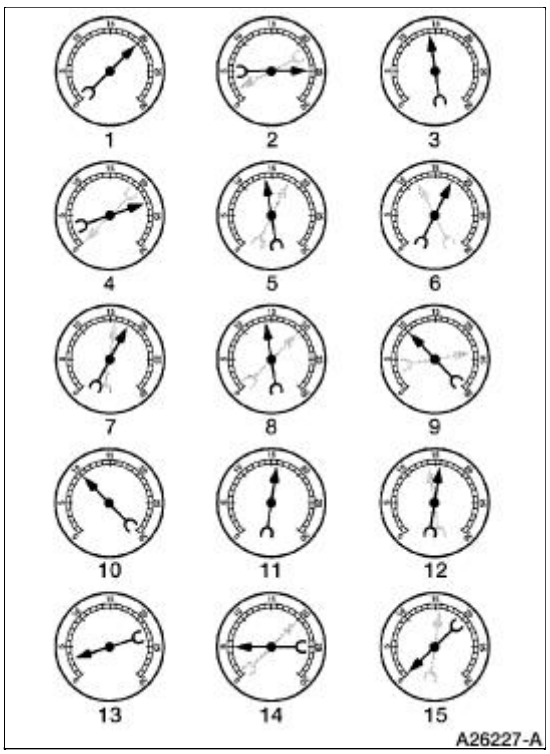
The reading should be steady. If necessary, adjust the gauge damper control (where used) if the needle is fluttering rapidly. Adjust the damper until the needle moves easily without excessive flutter.

Intake Manifold Vacuum Test—Interpreting Vacuum Gauge Readings

A careful study of the vacuum gauge reading while the engine is idling will help pinpoint trouble areas. Always conduct other appropriate tests before arriving at a final diagnostic decision. Vacuum gauge readings, although helpful, must be interpreted carefully.

Most vacuum gauges have a normal band indicated on the gauge face.

The following are potential gauge readings. Some are normal; others should be investigated further.



1. NORMAL READING: Needle between 51-74 kPa (15-22 in-Hg) and holding steady.

2. NORMAL READING DURING RAPID ACCELERATION AND DECELERATION: When the engine is rapidly accelerated (dotted needle), the needle will drop to a low reading (not to zero). When the throttle is suddenly released, the needle will snap back up to a higher than normal figure.

3. NORMAL FOR HIGH-LIFT CAMSHAFT WITH LARGE OVERLAP: The needle will register as low as 51 kPa (15 in-Hg) but will be relatively steady. Some oscillation is normal.

4. WORN RINGS OR DILUTED OIL: When the engine is accelerated (dotted needle), the needle drops to 0 kPa (0 in-Hg). Upon deceleration, the needle runs slightly above 74 kPa (22 in-Hg).

5. STICKING VALVES: When the needle (dotted) remains steady at a normal vacuum but occasionally flicks (sharp, fast movement) down and back about 13 kPa (4 in-Hg), one or more valves may be sticking.

6. BURNED OR WARPED VALVES: A regular, evenly-spaced, downscale flicking of the needle indicates one or more burned or warped valves. Insufficient hydraulic lash adjuster or hydraulic lash adjuster (HLA) clearance will also cause this reaction.

7. POOR VALVE SEATING: A small but regular downscale flicking can mean one or more valves are not seating.

8. WORN VALVE GUIDES: When the needle oscillates over about a 13 kPa (4 in-Hg) range at idle speed, the valve guides could be worn. As engine speed increases, the needle will become steady if guides are responsible.

9. WEAK VALVE SPRINGS: When the needle oscillation becomes more violent as engine rpm is increased, weak valve springs are indicated. The reading at idle could be relatively steady.

10. LATE VALVE TIMING: A steady but low reading could be caused by late valve timing.

11. IGNITION TIMING RETARDING: Retarded ignition timing will produce a steady but somewhat low reading.

12. INSUFFICIENT SPARK PLUG GAP: When spark plugs are gapped too close, a regular, small pulsation of the needle can occur.

13. INTAKE LEAK: A low, steady reading can be caused by an intake manifold or throttle body gasket leak.

14. BLOWN HEAD GASKET: A regular drop of fair magnitude can be caused by a blown head gasket or warped cylinder head-to-cylinder block surface.

15. RESTRICTED EXHAUST SYSTEM: When the engine is first started and is idled, the reading may be normal, but as the engine rpm is increased, the back pressure caused by a clogged muffler (5230), kinked tail pipe or other concerns will cause the needle to slowly drop to 0 kPa (0 in-Hg). The needle then may slowly rise. Excessive exhaust clogging will cause the needle to drop to a low point even if the engine is only idling.

16. When vacuum leaks are indicated, search out and correct the cause. Excess air leaking into the system will upset the fuel mixture and cause concerns such as rough idle, missing on acceleration or burned valves. If the leak exists in an accessory unit such as the power brake booster (2005), the unit will not function correctly. Always fix vacuum leaks.

Excessive Engine Oil Consumption

The amount of oil an engine uses will vary with the way the vehicle is driven in addition to normal engine-to-engine variation. This is especially true during the first 16,100 km (10,000 miles) when a new engine is being broken in or until certain internal engine components become conditioned. Vehicles used in heavy-duty operation may use more oil. The following are examples of heavy-duty operation:

- trailer towing applications
- severe loading applications
- sustained high speed operation

Engines need oil to lubricate the following internal components:

- cylinder block cylinder walls
- pistons and piston, pin and rings (6102)
- intake and exhaust valve stems
- intake and exhaust valve guides
- all internal engine components

When the pistons move downward, a thin film of oil is left on the cylinder walls. As the vehicle is operated, some oil is also drawn into the combustion chambers past the intake and exhaust valve stem seals and burned.

The following is a partial list of conditions that can affect oil consumption rates:

- engine duty cycle
- operator driving habits
- ambient temperature
- quality and viscosity of the oil

Operation under varying conditions can frequently be misleading. A vehicle that has been run for several thousand miles on short trips or in below-freezing ambient temperatures may have consumed a "normal" amount of oil. However, when checking the engine oil level, it may measure up to the FULL or MAX on the oil level dipstick due to dilution (condensation and fuel) in the engine crankcase. The vehicle might then be driven at high speeds on the highway where the condensation and fuel boil off. The next time the engine oil is checked, it may appear that a liter (quart) of oil was used in about 160 km (100 miles). This perceived 160 km (100 miles) per liter (quart) oil consumption rate causes customer concern even though the actual overall oil consumption rate is about 2,400 km (1,500 miles) per liter (quart).

Make sure the selected engine oil meets the current recommended API performance category with SAE viscosity grade as shown in the vehicle Owner's Guide. It is also important that the engine oil is changed at the intervals specified. Refer to the vehicle Owner's Guide.

Oil Pressure Test

1. Disconnect and remove the oil pressure sensor (9278) from the engine.
2. Connect the Oil Pressure Gauge to the oil pressure sender oil galley port.
3. Run the engine until normal operating temperature is reached.
4. Run the engine at the specified rpm and record the gauge reading.
5. The oil pressure should be within specifications; refer to the specification chart in the appropriate engine section.
6. If the pressure is not within specification, check the following possible sources:
    - insufficient oil
    - oil leakage
    - worn or damaged oil pump
    - oil pump screen cover and tube (6622)
    - excessive main bearing clearance

- excessive connecting rod bearing clearance

Valve Train Analysis—Engine Off—Valve Cover Removed

Check for damaged or severely worn parts and correct assembly. Make sure correct parts are used with the static engine analysis as follows.

Valve Train Analysis—Engine Off, Rocker Arm

- Check for loose mounting bolts, studs and nuts.
- Check for plugged oil feed in the rocker arms (6564) or cylinder head.

Valve Train Analysis—Engine Off, Camshaft Roller Followers and Hydraulic Lash Adjusters, Overhead Camshaft

- Check for loose mounting bolts on camshaft carriers.
- Check for plugged oil feed in the camshaft roller followers, lash adjusters or cylinder heads.

Valve Train Analysis—Engine Off, Camshaft—Engines

- Check for broken or damaged parts.

Valve Train Analysis—Engine Off, Push Rods

- Check for bent push rods (6565) and restricted oil passage.

Valve Train Analysis—Valve Springs

- Check for broken or damaged parts.

Valve Train Analysis—Engine Off, Valve Spring Retainer and Valve Spring Retainer Keys

- Check for correct seating of the valve spring retainer key (6518) on the valve stem and in valve spring retainer (6514).
- Check for correct seating on the valve stem.

Valve Train Analysis—Engine Off, Valves and Cylinder Head

- Check for plugged oil drain back holes.
- Check for worn or damaged valve tips.
- Check for missing or damaged guide-mounted valve stem seal.
- Check collapsed valve tappet gap.
- Check installed valve spring height.
- Check for missing or worn valve spring seats.
- Check for plugged oil metering orifice in cylinder head oil reservoir (if equipped).

Static checks (engine off) are to be made on the engine prior to the dynamic procedure.

Valve Train Analysis—Engine Running

- Start the engine and, while idling, check for correct operation of all parts. Check the following:

Valve Train Analysis—Engine Running, Valves and Cylinder Head

- Check for plugged oil drain back holes.
- Check for missing or damaged valve stem seals or guide mounted valve stem seals.
- Check for a plugged oil metering orifice in the cylinder head oil reservoir (4.6L engine only).

If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1,200 rpm with the transmission in NEUTRAL and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and camshaft roller followers are well oiled. With the valve covers (6582) off, some oil splash may overshoot camshaft roller followers.

Valve Train Analysis—Engine Running, Camshaft Lobe Lift—OHC Engines

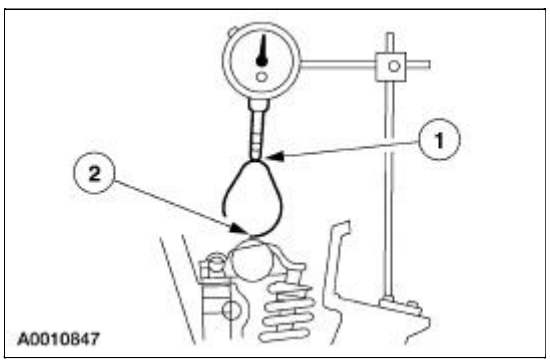
Check the lift of each camshaft lobe in consecutive order and make a note of the readings.

1. Remove the valve covers.

2. Remove the spark plugs.

3. Install the Dial Indicator Gauge with Holding Fixture so the rounded tip of indicator is on top of the camshaft lobe and on the same plane as the valve tappet.

4. Rotate the crankshaft using a breaker bar and socket attached to the crankshaft pulley retainer bolt. Rotate the crankshaft until the base circle of the camshaft lobe is reached.



5. Zero the dial indicator. Continue to rotate the crankshaft until the (1) high-lift point of the camshaft lobe is in the fully-raised position (highest indicator reading).

6. To check the accuracy of the original indicator reading, continue to rotate crankshaft until the (2) base circle is reached. The indicator reading should be zero. If zero reading is not obtained, repeat Steps 1 through 6.

7. **NOTE:** If the lift on any lobe is below specified service limits, install a new camshaft, and new camshaft roller followers.

   Remove the Dial Indicator Gauge with Holding Fixture.

8. Install the spark plugs.

9. Install the valve covers.

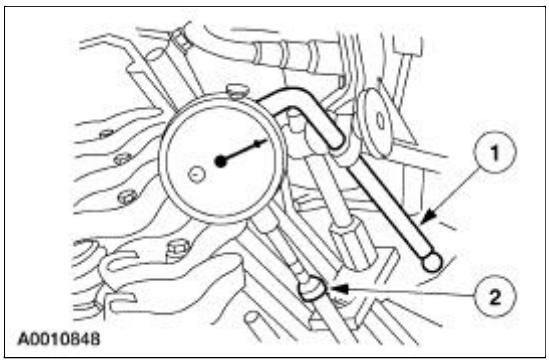
Valve Train Analysis—Engine Running, Camshaft Lobe Lift—Push Rod Engine

Check the lift of each lobe in consecutive order and make a note of the readings.

1. Remove the valve covers.

2. Remove the rocker arm seat bolts, rocker arm seat (6A528) and rocker arms.

Typical Engine With Push Rods



3. Make sure the valve tappet is seated against camshaft (6250). Install (1) Dial Indicator Gauge with Holding Fixture so the ball socket adapter of the indicator is on top of the valve tappet or (2) Dial Indicator Gauge Adapter is on top of push rod and in same plane as valve tappet push rod movement.

4. Remove the spark plugs.

5. Connect an auxiliary starter switch in the starting circuit. Crank the engine with ignition switch in OFF position. Bump crankshaft over until valve tappet is on base circle of camshaft lobe. At this point, valve tappet will be in its lowest position. If checking during engine assembly, turn crankshaft using a socket or ratchet.

6. Zero the dial indicator. Continue to rotate crankshaft slowly until valve tappet is in fully-raised position (highest indicator reading).

7. **NOTE:** If lift on any lobe is below specified service limits, install a new camshaft, and new valve tappets.

   Remove the Dial Indicator with Holding Fixture, Dial Indicator Gauge Adapter, and auxiliary starter switch.

8. Install rocker arm seats, rocker arms and rocker arm seat bolts.

9. Install valve covers.

10. Install spark plugs.

Valve Train Analysis—Engine Running, Valve Tappet

Valve tappet noise can be caused by any of the following:

- excessive valve tappet gap (collapsed)

- incorrectly functioning valve tappet
- air in lubrication system
- excessive valve guide wear
- low oil pressure

Excessive collapsed valve tappet gap can be caused by loose rocker arm seat bolts/nuts, incorrect initial adjustment or wear of valve tappet face, or worn roller valve tappets, push rod (6565), rocker arm (6564), rocker arm seat or valve tip. With valve tappet collapsed, check gap between the valve tip and the rocker arm to determine if any other valve train parts are damaged, worn or out of adjustment.

An incorrectly functioning valve tappet can be sticking, caused by contaminants or varnish inside the tappet. The tappet can have a check valve that is not functioning correctly, which can be caused by an obstruction, such as dirt or chips that prevent the check valve from closing, or a broken check valve spring. A tappet with a leakdown time out of specification can cause tappet noise. If no other cause for noisy valve tappets can be found, the leakdown rate should be checked and new valve tappets installed if found to be out of specification.

Assembled valve tappets can be tested with Hydraulic Tappet Leakdown Tester to check the leakdown rate. The leakdown rate specification is the time in seconds for the plunger to move a specified distance while under a 22.7 kg (50 lb) load.

Air bubbles in the lubrication system will prevent the valve tappet from supporting the valve spring load. This can be caused by too high or too low an oil level in the oil pan or by air being drawn into the system through a hole, crack or leaking gasket on the oil pump screen cover and tube.

Sprockets

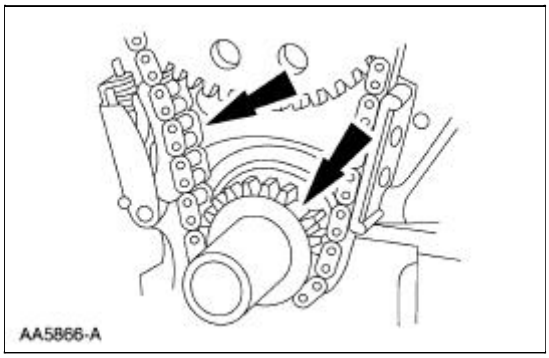
1. **WARNING: To avoid the possibility of personal injury or damage to the vehicle, do not operate the engine with the hood open until the fan blade has been examined for possible cracks and separation.**

   NOTE: Specifications show the expected minimum or maximum condition. Refer to the appropriate section in Group 303 for the procedure.

   NOTE: If a component fails to meet the specifications, it is necessary to install a new component or refinish. If the component can be refinished, wear limits are provided as an aid to making a decision. A new component must be installed for any component that fails to meet specifications and cannot be refinished.

   Inspect the timing chain/belt and the sprockets.

   - Install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



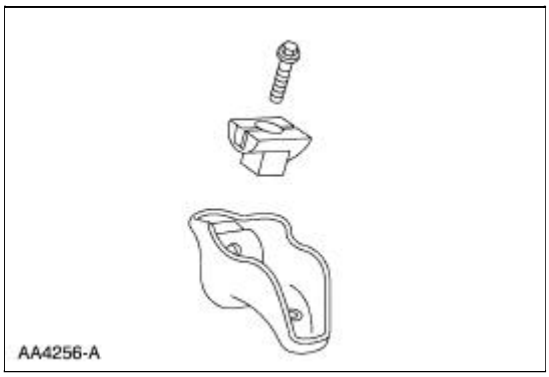
Rocker Arms —Cleaning

1. Clean all parts thoroughly. Make sure all oil passages are open.
2. Make sure oil passage in the push rod/valve tappet end of the rocker arm (6564) is open.

Rocker Arms —Inspection

CAUTION: Do not attempt to true surfaces by grinding. Check the rocker arm pad, side rails and seat for excessive wear, cracks, nicks or burrs. Check the rocker arm seat bolt for stripped or broken threads. Install new components as ncessary or possible damage may occur.

1. Inspect the rocker arm push rod bore for nicks, scratches, scores or scuffs. Install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



2. Inspect the pad at the valve end of the rocker arm for indications of scuffing or abnormal wear. If the pad is grooved, install a new rocker arm. Refer to the appropriate section in Group 303 for the procedure.

Push Rods —Cleaning

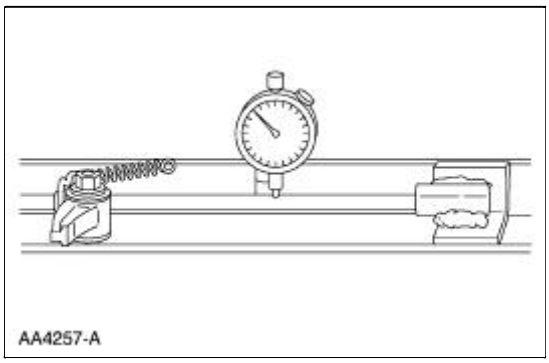
1. Clean the push rods (6565) in a suitable solvent. Blow out the oil passage in the push rods with compressed air.

Push Rods —Inspection

1. **CAUTION: Do not attempt to straighten push rods.**

   Check the ends of the push rods for nicks, grooves, roughness or excessive wear. Install new push rods as necessary. Refer to the appropriate section in Group 303 for the procedure.

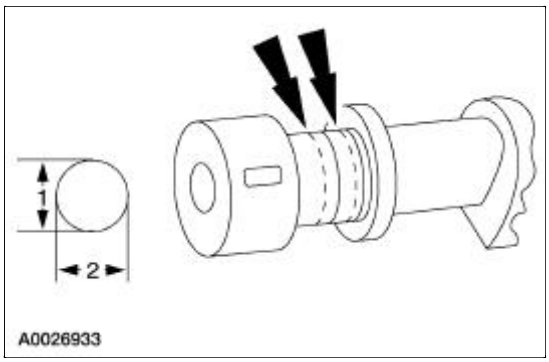
   - The push rods can be checked for straightness while they are installed in the engine by rotating them with the valve closed.
   - They also can be checked using a Dial Indicator with Bracketry.



2. If the push rod is bent beyond specifications, install a new push rod. Refer to the appropriate section in Group 303 for the procedure.

Camshaft Journal —Diameter

1. Measure each camshaft journal diameter in two directions.
    - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.

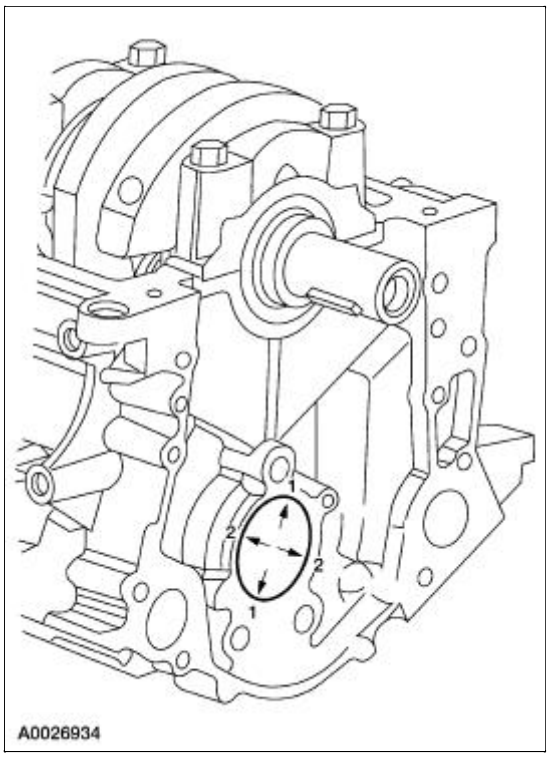


Camshaft Journal —Clearance, Push Rod Engines, Micrometer Method

1. **NOTE:** The camshaft journals must meet specifications before checking camshaft journal clearance.

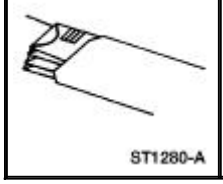
   Measure each camshaft bearing (6261) in two directions.

   - Subtract the camshaft journal diameter from the camshaft bearing diameter.



Camshaft Journal —Clearance, Plastigage Method

Special Tool(s)

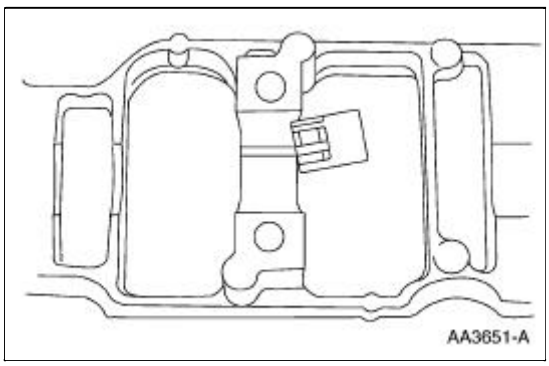
 ST1280-A	Plastigage 303-D031 (D81L-6002-B) or equivalent

NOTE: The camshaft journals must meet specifications before checking camshaft journal clearance.

1. Remove the camshaft bearing cap and lay Plastigage across the surface. Refer to the appropriate section in Group 303 for the procedure.

2. **NOTE:** Do not turn the camshaft while carrying out this procedure.

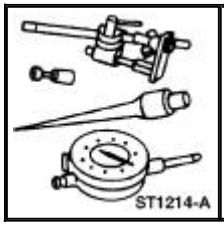
   Position the camshaft bearing cap and install the bolts. Refer to the appropriate section in Group 303 for the procedure.

   
   AA3651-A

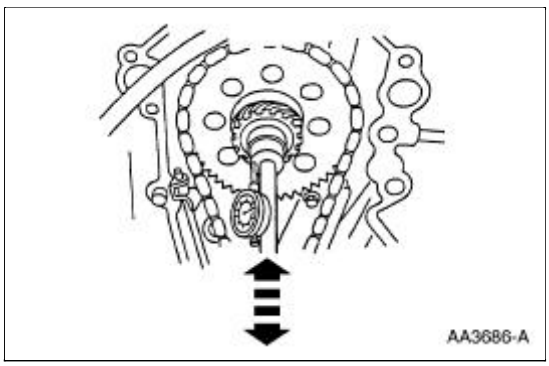
3. Use Plastigage to verify the camshaft journal clearance.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.

Camshaft End Play —Push Rod Engines

Special Tool(s)

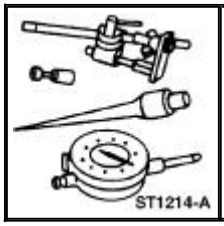
 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent

1. Remove the valve tappets. Refer to the appropriate section in Group 303 for the procedure.
2. Use a Dial Indicator Gauge with Holding Fixture to measure camshaft end play.
3. Position the camshaft to the rear of the cylinder block.
4. Zero the indicator.
5. Move the camshaft to the front of the cylinder block. Note and record the camshaft end play.
   - If the camshaft end play exceeds specifications, install a new camshaft thrust plate. Refer to the appropriate section in Group 303 for the procedure.

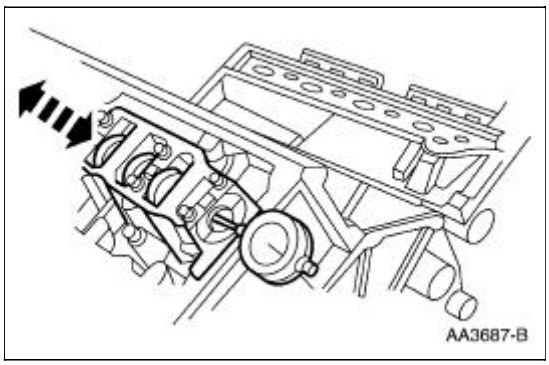


Camshaft End Play —OHC Engines

Special Tool(s)

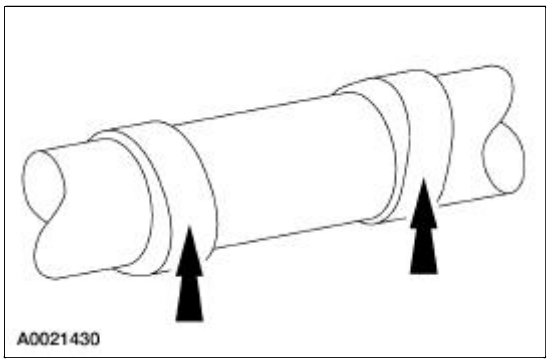
 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent

1. Remove the roller followers. Refer to the appropriate section in Group 303 for the procedure.
2. Use a Dial Indicator Gauge with Holding Fixture to measure camshaft end play.
3. Position the camshaft to the rear of the cylinder head.
4. Zero the indicator.
5. Move the camshaft to the front of the cylinder head. Note and record the camshaft end play.
   - If camshaft end play exceeds specifications, install new camshaft and recheck end play. Refer to the appropriate section in Group 303 for the procedure.
   - If camshaft end play exceeds specification after camshaft installation, install a new cylinder head. Refer to the appropriate section in Group 303 for the procedure.



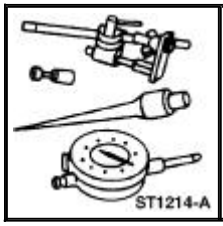
Camshaft —Lobe Surface

1. Inspect camshaft lobes for pitting or damage in the contact area. Minor pitting is acceptable outside the contact area.
    - If excessive pitting or damage is present, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.

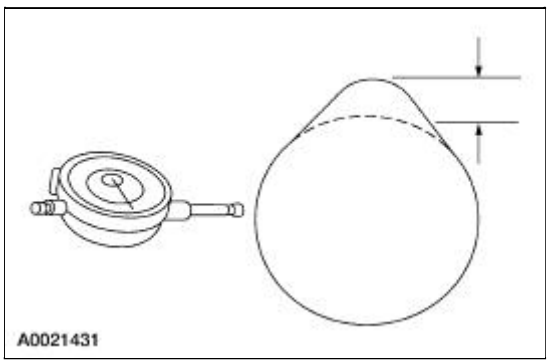


Camshaft Lobe Lift

Special Tool(s)

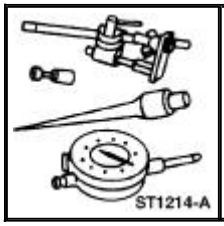
 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent

1. Use a Dial Indicator Gauge with Holding Fixture to measure camshaft intake/exhaust lobe lift.
   - Rotate the camshaft and subtract the lowest indicator reading from the highest indicator reading to figure the camshaft lobe lift.
   - Refer to the appropriate section in Group 303 for the procedure.



Camshaft Runout

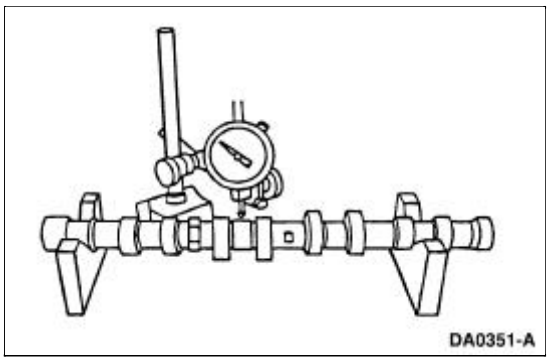
Special Tool(s)

 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent

1. **NOTE:** Camshaft journals must be within specifications before checking runout.

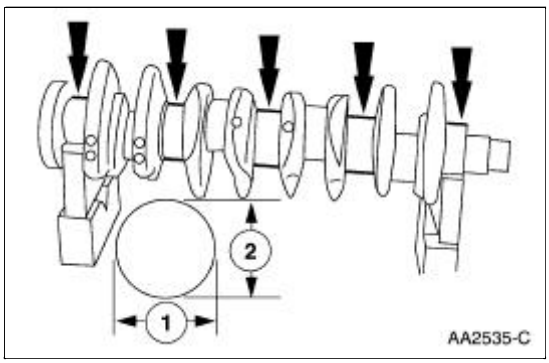
   Use a Dial Indicator Gauge with Holding Fixture to measure the camshaft runout.

   - Rotate the camshaft and subtract the lowest indicator reading from the highest indicator reading.
   - For additional information, refer to the specification chart in the appropriate engine section.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.


DA0351-A

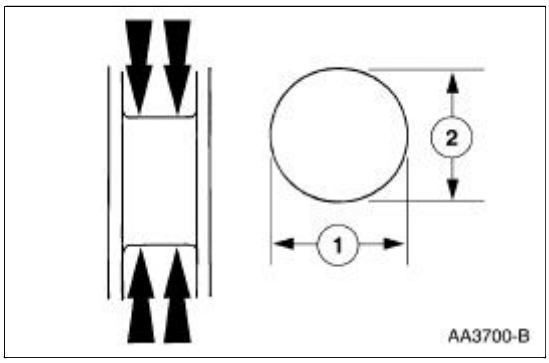
Crankshaft Main Bearing Journal —Diameter

1. Measure each of the crankshaft main bearing journal diameters in at least two directions.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Crankshaft Main Bearing Journal —Taper

1. Measure each of the crankshaft main bearing journal diameters in at least two directions at each end of the main bearing journal.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



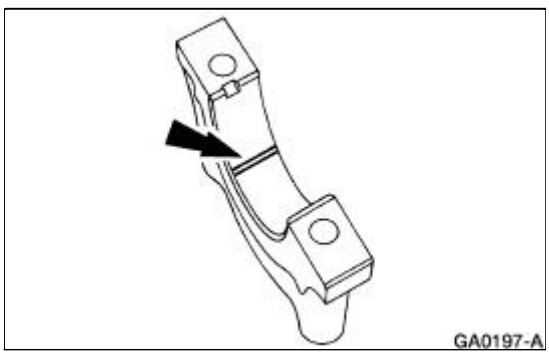
Crankshaft Main Bearing Journal —Clearance

Special Tool(s)

ST1280-A	Plastigage 303-D031 (D81L-6002-B) or equivalent

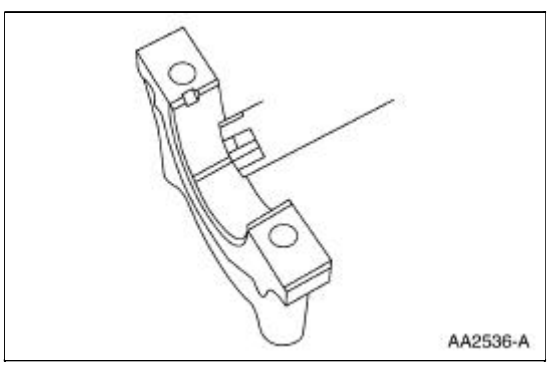
NOTE: Crankshaft main bearing journals must be within specifications before checking journal clearance.

1. Remove the crankshaft main bearing caps and crankshaft main bearing.
2. Lay a piece of Plastigage across the face of each crankshaft main bearing surface.


GA0197-A

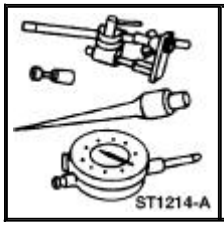
3. **NOTE:** Do not turn the crankshaft while carrying out this procedure.

   Install and remove the crankshaft main bearing cap.
4. Verify the crankshaft journal clearance.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.


AA2536-A

Crankshaft End Play

Special Tool(s)

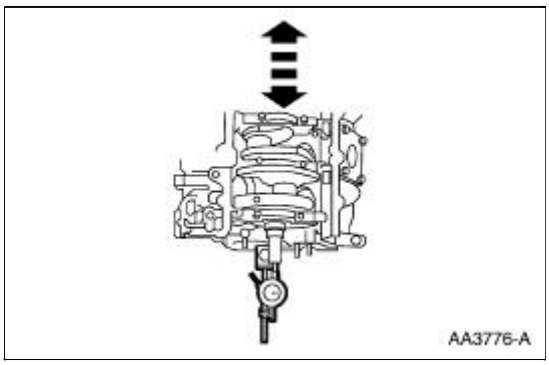
 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent

1. Measure the crankshaft end play. Use a Dial Indicator Gauge with Holding Fixture to measure crankshaft end play.

2. Position the crankshaft to the rear of the cylinder block.

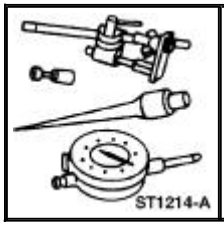
3. Zero the indicator.

4. Move the crankshaft to the front of the cylinder block. Note and record the crankshaft end play.
   - If crankshaft end play exceeds specifications, install a new crankshaft thrust washer (6334) or crankshaft thrust main bearing (6337). Refer to the appropriate section in Group 303 for the procedure.



Crankshaft Runout

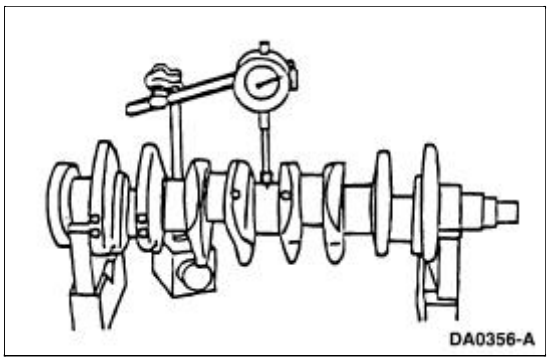
Special Tool(s)

 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent

1. **NOTE:** Crankshaft main bearing journals must be within specifications before checking runout.

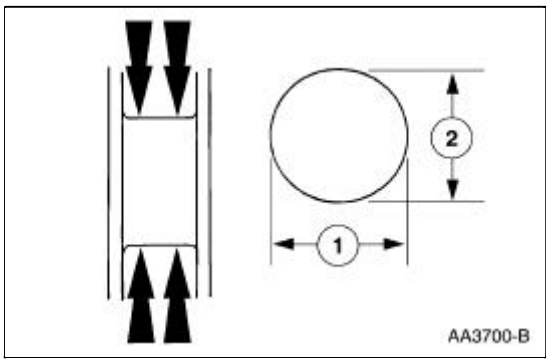
   Use the Dial Indicator Gauge with Holding Fixture to measure the crankshaft runout.

   - Refer to the appropriate section in Group 303 for the procedure.
   - Rotate the crankshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the crankshaft runout. If it is out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



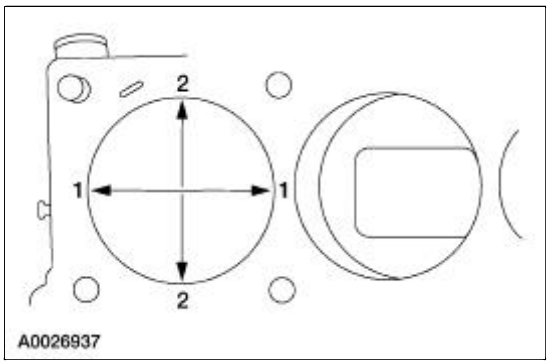
Crankshaft —Connecting Rod Journal Taper, Out of Round

1. Measure the crankshaft connecting rod journal diameters in two directions perpendicular to one another at each end of the connecting rod journal. The difference in the measurements from one end to the other is the taper. Verify measurement is within the wear limit.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



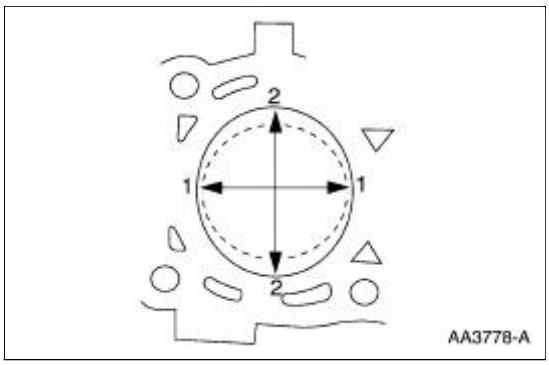
Cylinder Bore —Taper

1. Measure the cylinder bore at the top, middle, and bottom of piston ring travel in two directions as indicated. Verify the cylinder bore is within the wear limit. The difference indicates the cylinder bore taper. Bore the cylinder to the next oversize.
   - Refer to the appropriate section in Group 303 for the procedure.



Cylinder Bore —Out-of-Round

1. Measure the cylinder bore in two directions. The difference is the out-of-round. Verify the out-of-round is within the wear limit and bore the cylinder to the next oversize limit.
   - Refer to the appropriate section in Group 303 for the procedure.



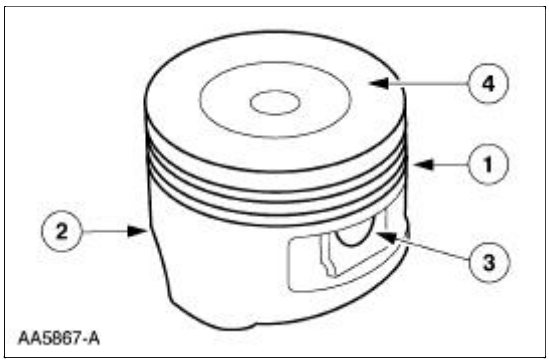
Piston Inspection

Special Tool(s)

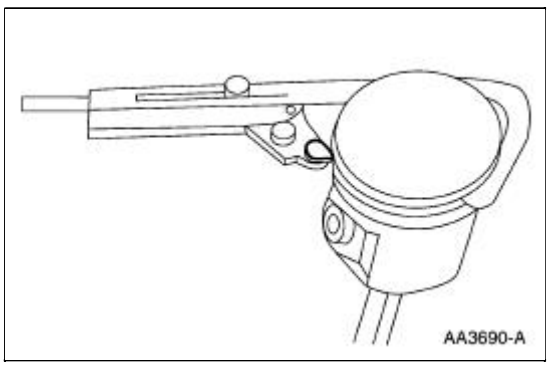
ST1279-A	Scraper, Piston Ring Groove 303-D033 (D81L-6002-D) or equivalent

CAUTION: Do not use a caustic cleaning solution or a wire brush to clean the pistons or damage can occur.

1. Clean and inspect the (1) ring lands, (2) skirts, (3) pin bosses, and the (4) tops of the pistons. If wear marks, scores or glazing is found on the piston skirt, check for a bent or twisted connecting rod.



2. Use the Piston Ring Groove Scraper to clean the piston ring grooves.
   - Make sure the oil ring holes are clean.



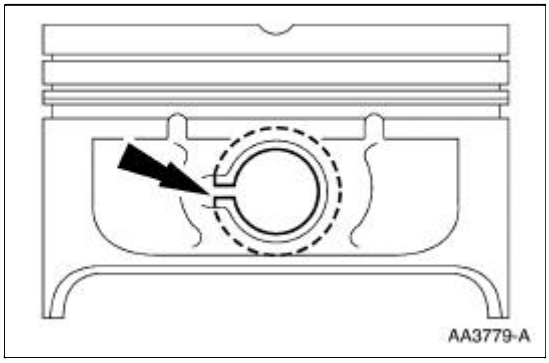
Piston —Pin to Bore Diameter

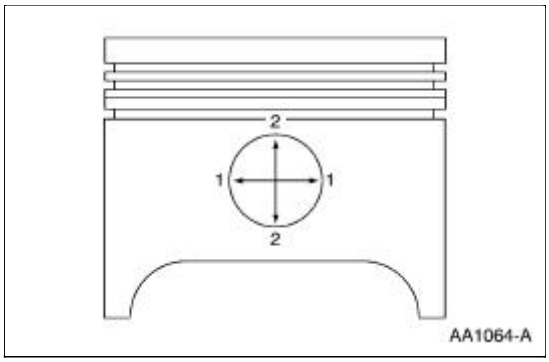
1. **WARNING: Cover the end of the pin bore with a hand or shop rag when removing the retainer ring, since it has a tendency to spring out. Wear eye protection.**

   NOTE: Piston and piston pins are a matched set and should not be interchanged.

   Measure the piston pin bore diameter in two directions on each side. Verify the diameter is within specification.

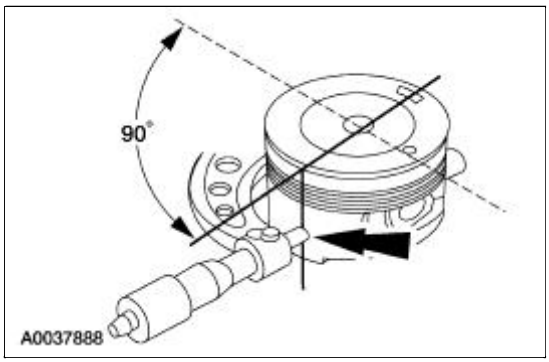
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.





Piston —Diameter

1. Measure the piston diameter 90 degrees from the piston pin at the point indicated. Refer to the appropriate section in Group 303 for the procedure.
    - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



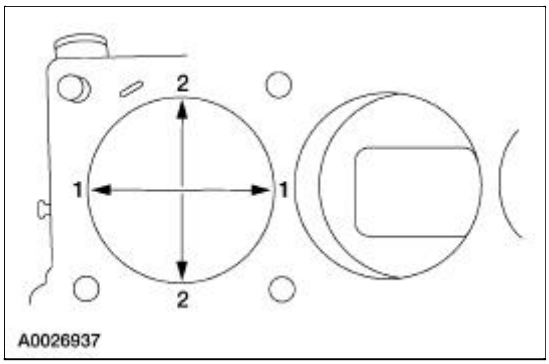
Piston —to Cylinder Bore Clearance

1. Subtract the piston diameter from the cylinder bore diameter to find the piston-to-cylinder bore clearance.

Piston —Selection

NOTE: The cylinder bore must be within the specifications for taper and out-of-round before fitting a piston.

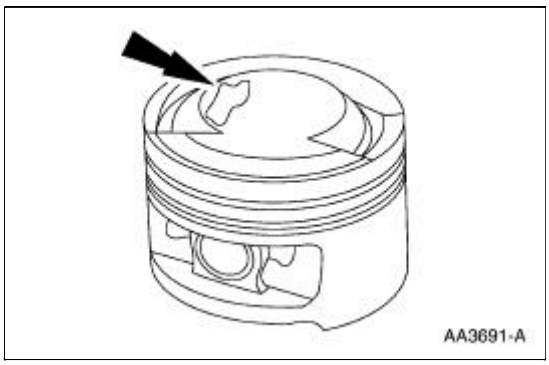
1. Select a piston size based on the cylinder bore.



2. **NOTE:** For precision fit, new pistons are divided into three categories within each size range based on their relative position within the range. A paint spot on the new pistons indicates the position within the size range.

   Choose the piston with the correct paint color.

   - Refer to the appropriate section in Group 303 for the procedure.



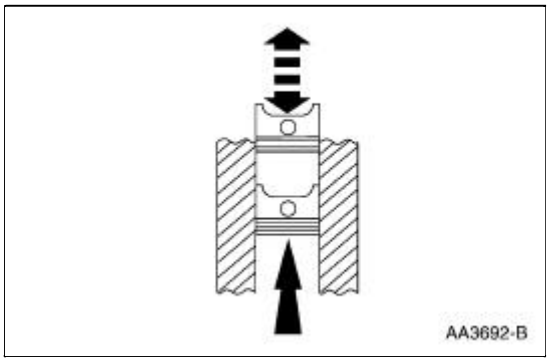
Piston —Ring End Gap

CAUTION: Use care when fitting piston rings to avoid possible damage to the piston ring or the cylinder bore.

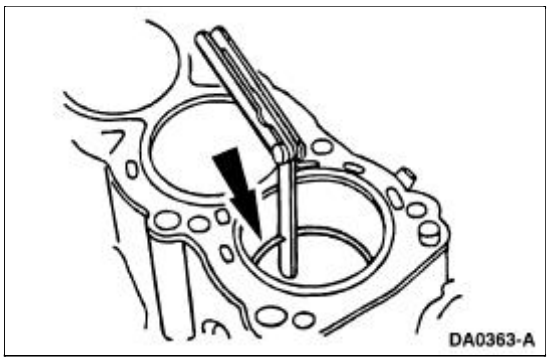
CAUTION: Piston rings should not be transferred from one piston to another.

NOTE: Cylinder bore must be within specification for taper and out-of-round.

1. Use a piston without rings to push a piston ring in a cylinder to the bottom of ring travel.

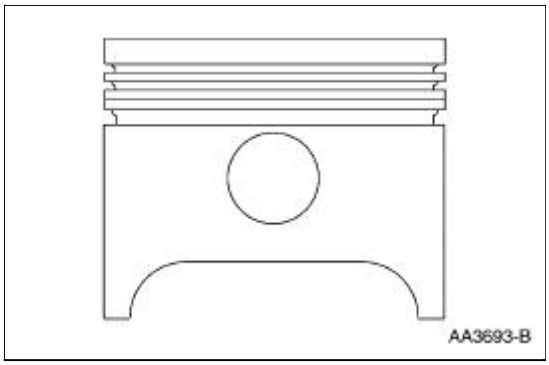


2. Use a feeler gauge to measure the top piston ring end gap and the second piston ring end gap.
   - Refer to the appropriate section in Group 303 for the procedure.

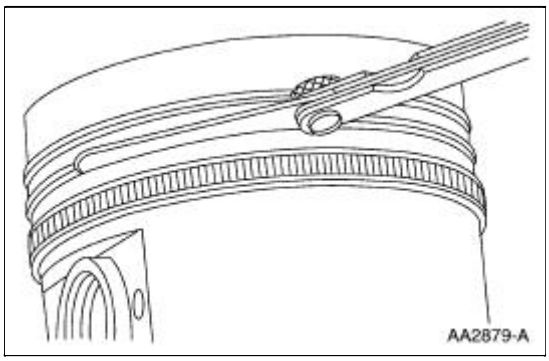


Piston —Ring-to-Groove Clearance

1. Inspect the piston for ring land damage or accelerated wear.

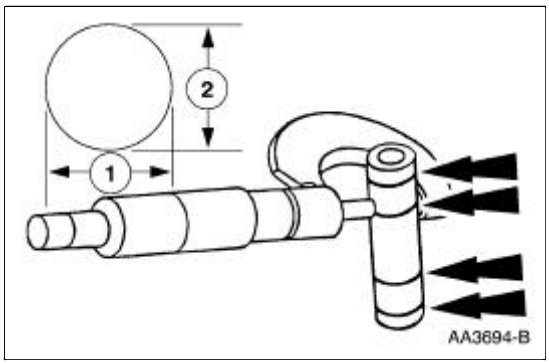


2. Measure the piston ring-to-groove clearance.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Piston —Pin Diameter

1. Measure the piston pin diameter in two directions at the points shown. Verify the diameter is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.

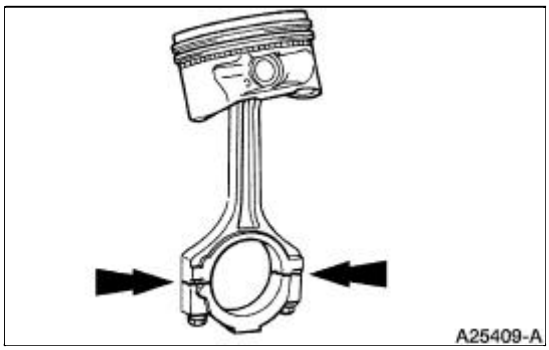


Connecting Rod —Cleaning

CAUTION: Do not use a caustic cleaning solution or damage to connecting rods can occur.

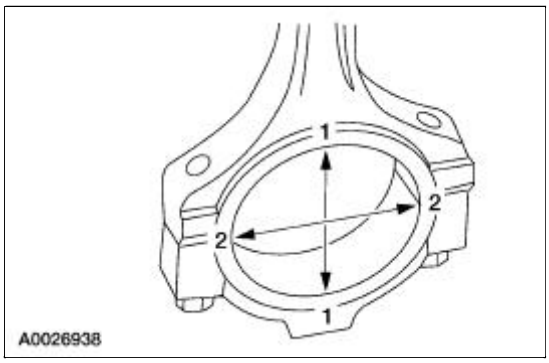
1. **NOTE:** The connecting rod large end is a matched set. The connecting rod cap must be installed on the original connecting rod in the original position. Do not reverse the cap. Parts are not interchangeable.

   Mark and separate the parts and clean with solvent. Clean the oil passages.



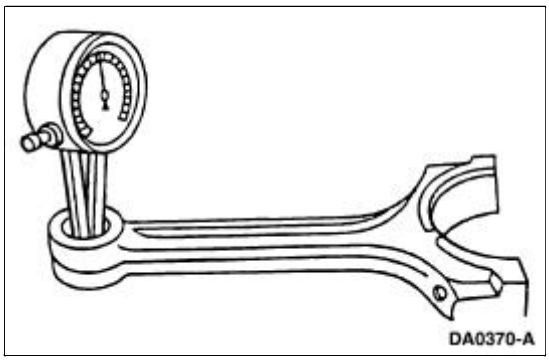
Connecting Rod —Large End Bore

1. Tighten the bolts to specification, then measure the bore in two directions. The difference is the connecting rod bore out-of-round. Verify the out-of-round is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



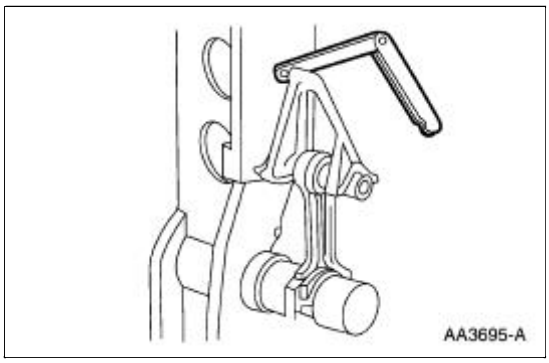
Connecting Rod —Bushing Diameter

1. Measure the inner diameter of the connecting rod bushing, if equipped. Verify the diameter is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



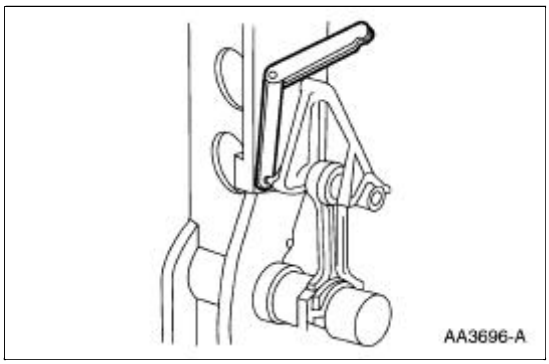
Connecting Rod —Bend

1. Measure the connecting rod bend on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the bend measurement is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



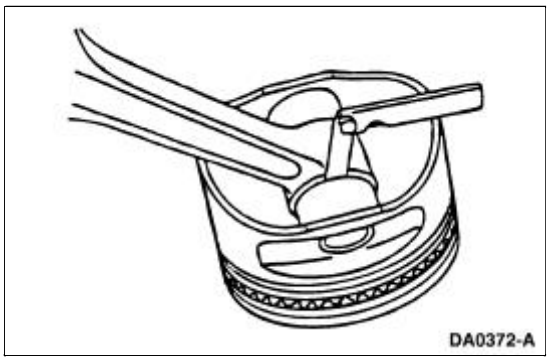
Connecting Rod —Twist

1. Measure the connecting rod twist on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the measurement is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Connecting Rod —Piston Pin Side Clearance

1. Measure the clearance between the connecting rod and the piston. Verify the measurement is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Connecting Rod —Bearing Journal Clearance

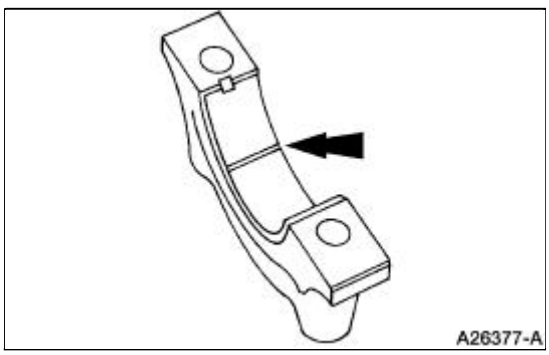
Special Tool(s)

ST1280-A	Plastigage 303-D031 (D81L-6002-B) or equivalent

NOTE: The crankshaft connecting rod journals must be within specifications to check the connecting rod bearing journal clearance.

1. Remove the connecting rod bearing cap.

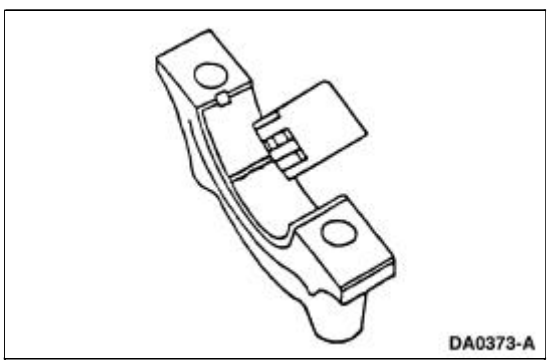
2. Position a piece of Plastigage across the bearing surface.



3. **NOTE:** Do not turn the crankshaft during this step.

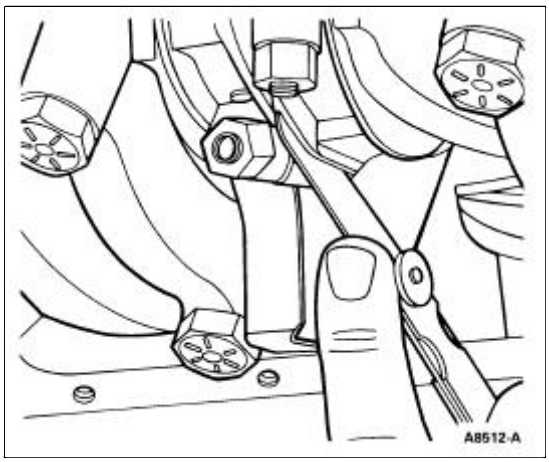
   Install and tighten to specifications, then remove the connecting rod bearing cap.

4. Measure the Plastigage to get the connecting rod bearing journal clearance. The Plastigage should be smooth and flat. A changing width indicates a tapered or damaged connecting rod or connecting rod bearing.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Connecting Rod —Side Clearance

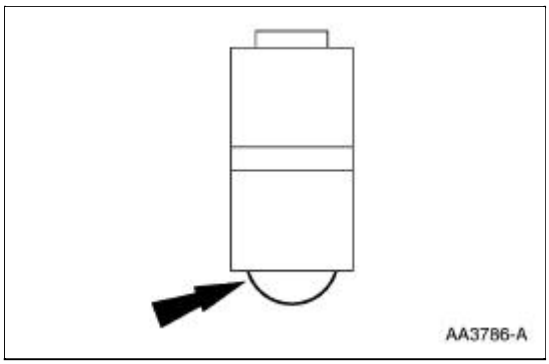
1. Measure the clearance between the connecting rod and the crankshaft. Verify the measurement is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



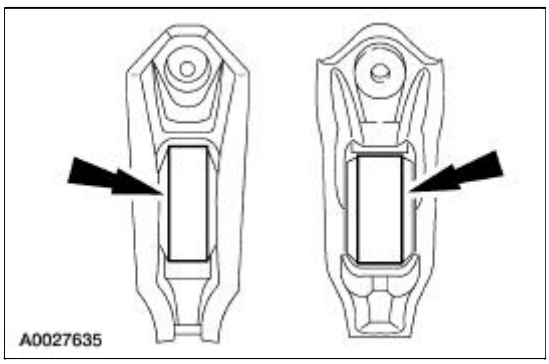
Roller Follower —Inspection

Push rod engines

1. Inspect the roller for flat spots or scoring. If any damage is found, inspect the camshaft lobes and valve tappet for damage.



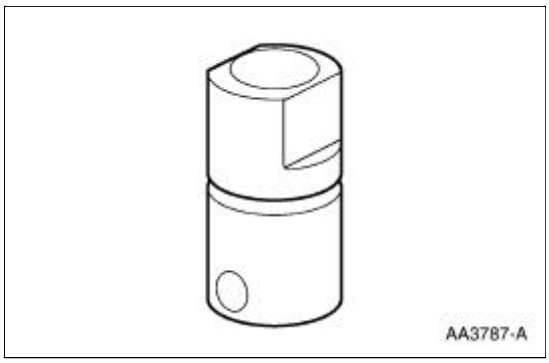
OHC engines



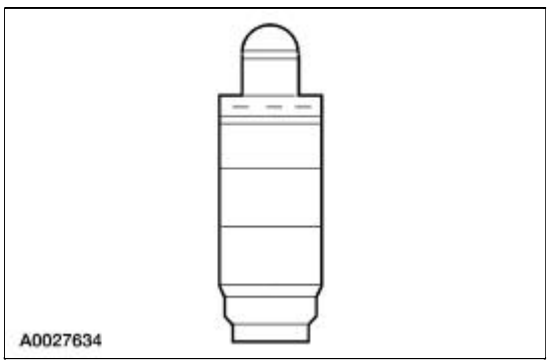
Valve Tappet —Inspection

Push rod engines

1. Inspect the hydraulic valve tappet and roller for damage. If any damage is found, inspect the camshaft lobes and valves for damage.

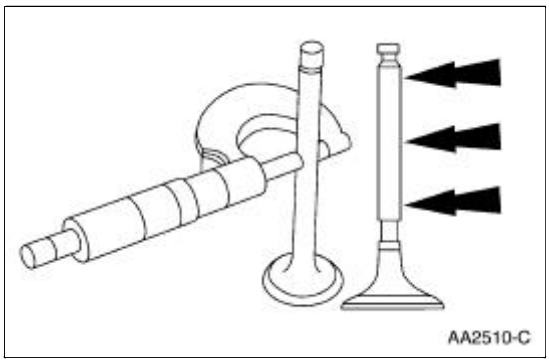


OHC engines



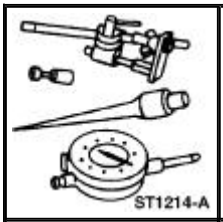
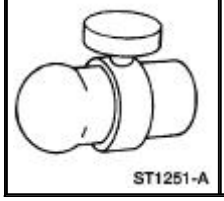
Valve —Stem Diameter

1. Measure the diameter of each intake and exhaust valve stem at the points shown. Verify the diameter is within specification.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Valve Stem to Valve Guide Clearance

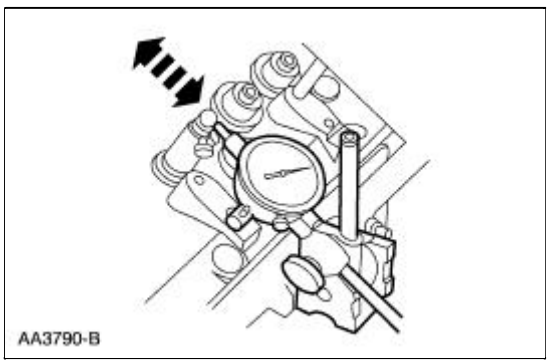
Special Tool(s)

 ST1214-A	Dial Indicator Gauge with Holding Fixture 100-002 (TOOL-4201-C) or equivalent
 ST1251-A	Clearance Gauge, Valve Guide 303-004 (TOOL-6505-E) or equivalent

NOTE: Valve stem diameter must be within specifications before checking valve stem to valve guide clearance.

1. **NOTE:** If necessary, use a magnetic base.

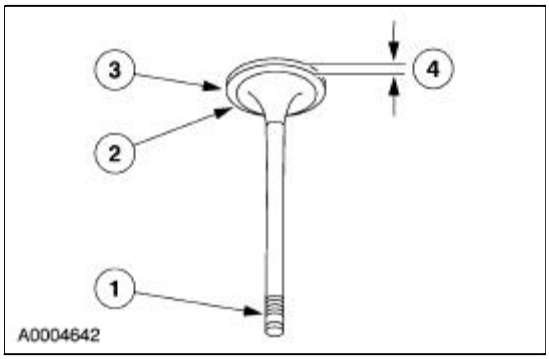
   Install a Valve Guide Clearance Gauge on the valve stem and install a Dial Indicator Gauge with Holding Fixture. Lower the valve until the Valve Guide Clearance Gauge contacts the upper surface of the valve guide.

   
   AA3790-B

2. Move the Valve Guide Clearance Gauge toward the indicator and zero the indicator. Move the Valve Guide Clearance Gauge away from the indicator and note the reading. The reading will be DOUBLE the valve stem-to-valve guide clearance. Valves with oversize stems will need to be installed if out of specification.

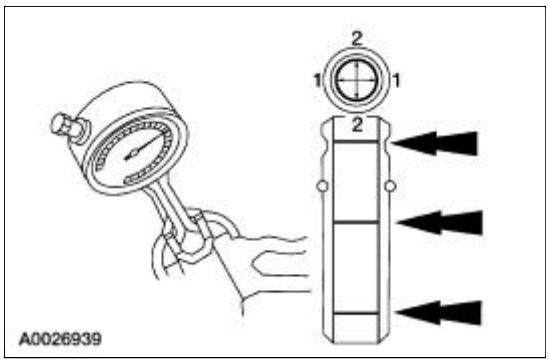
Valve —Inspection

1. Inspect the following valve areas:
    1. the end of the stem for grooves or scoring
    2. the valve face and the edge for pits, grooves or scores
    3. the valve head for signs of burning, erosion, warpage and cracking
    4. the valve margin for wear



Valve —Guide Inner Diameter

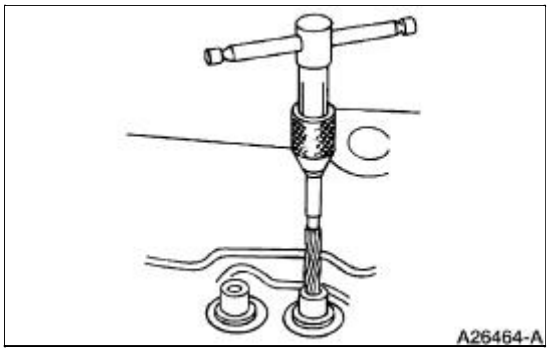
1. Measure the inner diameter of the valve guides in two directions where indicated.
   - Refer to the appropriate section in Group 303 for the procedure.



2. If the valve guide is not within specifications, ream the valve guide and install a valve with an oversize stem or remove the valve guide and install a new valve guide.

Valve —Guide Reaming

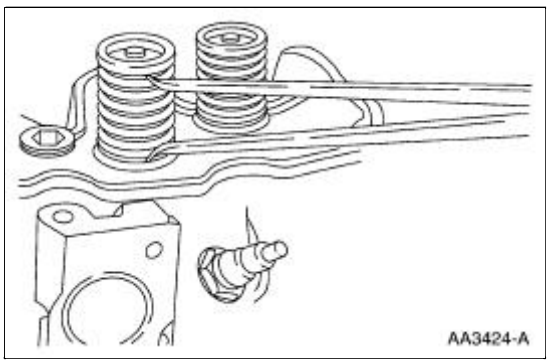
1. Use a hand-reaming kit to ream the valve guide.



2. Reface the valve seat.
3. Clean the sharp edges left by reaming.

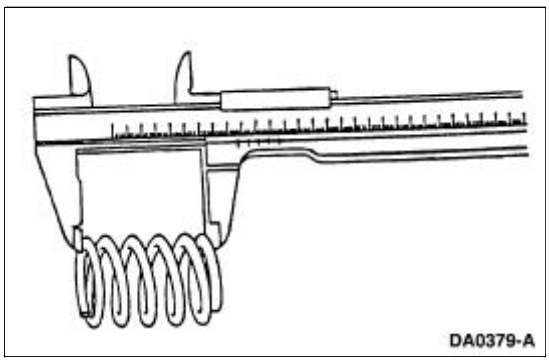
Valve —Spring Installed Length

1. Measure the installed length of each valve spring.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components. Refer to the appropriate section in Group 303 for the procedure.



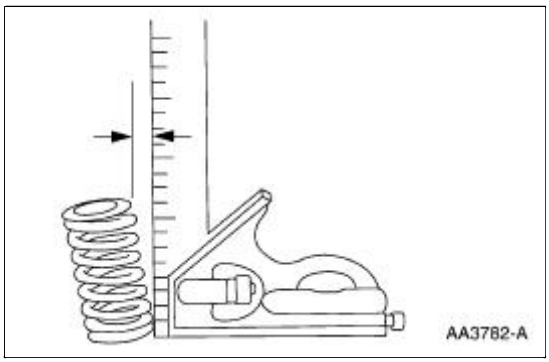
Valve —Spring Free Length

1. Measure the free length of each valve spring.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.



Valve —Spring Squareness

1. Measure the out-of-square on each valve spring.
   - Turn the valve spring and observe the space between the top of the valve spring and the square. Install a new valve spring if out of square. Refer to the appropriate section in Group 303 for the procedure.

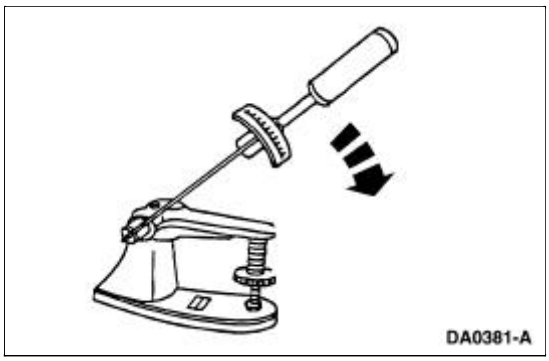


Valve Spring Strength

Special Tool(s)

ST1278-A	Pressure Gauge, Valve/Clutch Spring 303-006 (TOOL-6513-DD) or equivalent

1. Use a Valve/Clutch Spring Pressure Gauge to check the valve spring for correct strength at the specified valve spring length.
   - Refer to the appropriate section in Group 303 for the procedure.
   - If out of specification, install new components as necessary. Refer to the appropriate section in Group 303 for the procedure.

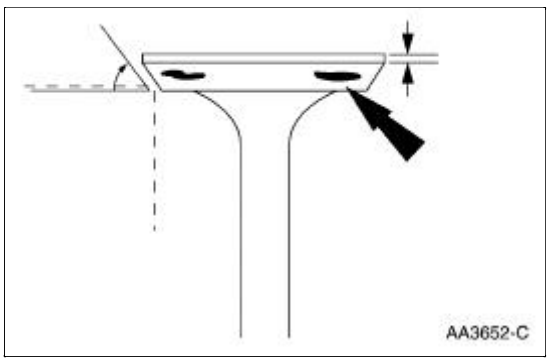


Valve —Seat Inspection

Valve and Seat Refacing Measurements

CAUTION: After grinding valves or valve seats, check valve clearance.

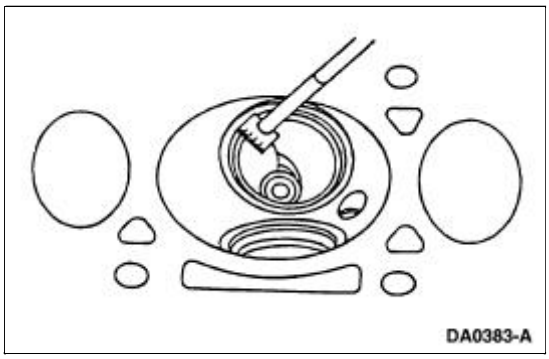
1. Check the valve head and seat.
   - Check valve angles.
   - Check margin width.
   - Refer to the appropriate section in Group 303 for the procedure.
   - Be sure margin width is within specification.



2. Inspect for abnormalities on the valve face and seat.

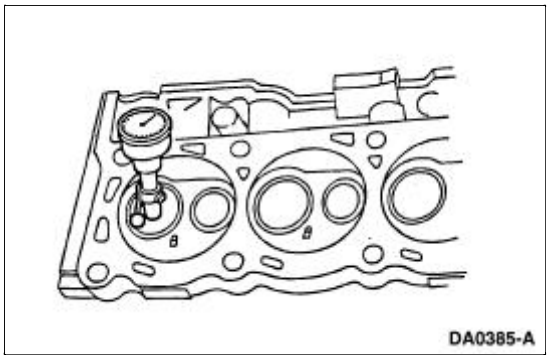
Valve —Seat Width

1. Measure the valve seat width. If necessary, grind the valve seat to specification.
   - Measure the intake valve seat width.
   - Measure the exhaust valve seat width.
   - Recheck the valve spring installed length after the seats have been ground, and shim the valve springs as necessary to achieve the correct installed spring length.
   - Refer to the appropriate section in Group 303 for the procedure.



Valve —Seat Runout

1. Use the Valve Seat Runout Gauge to check valve seat runout.

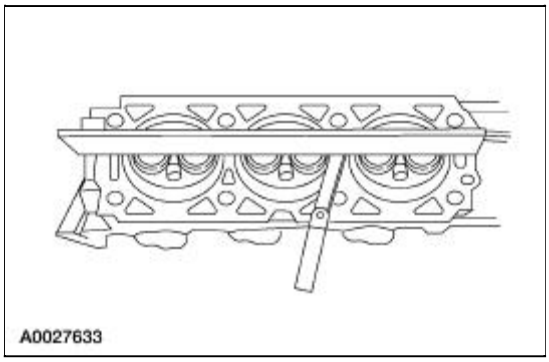


Cylinder Head —Distortion

Special Tool(s)

ST1246-A	Straight Edge 303-D039 (D83L-4201-A) or equivalent

1. Use a straight edge and a feeler gauge to inspect the cylinder head for flatness. If the cylinder head is distorted, install a new cylinder head.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Cylinder Bore —Cleaning

1. **CAUTION: If these procedures are not followed, rusting of the cylinder bores may occur.**

   Clean the cylinder bores with soap or detergent and water.

2. Thoroughly rinse with clean water and wipe dry with a clean, lint-free cloth.

3. Use a clean, lint-free cloth and lubricate the cylinder bores.
   - Use clean engine oil meeting Ford specification.

Cylinder Block Core Plug Replacement

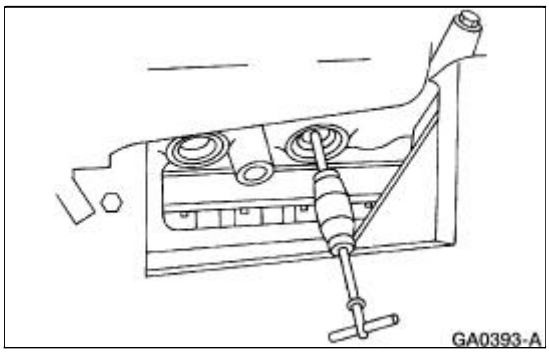
Special Tool(s)

ST1185-A	Slide Hammer 100-001 (T50T-100-A)

Material

Item	Specification
Threadlock® 262 E2FZ-19554-B or equivalent	WSK-M2G351-A6

1. Use a slide hammer or tools suitable to remove the cylinder block core plug.



2. Inspect the cylinder block plug bore for any damage that would interfere with the correct sealing of the plug. If the cylinder block plug bore is damaged, bore for the next oversize plug.

3. **NOTE:** Oversize plugs are identified by the OS stamped in the flat located on the cup side of the plug.

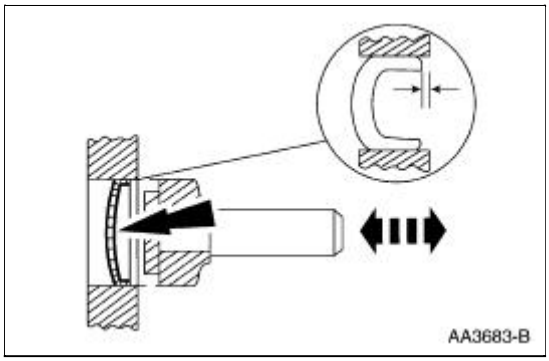
   Coat the cylinder block core plug and bore lightly with Threadlock® 262 and install the cylinder block core plug.

Cup-Type

4. **CAUTION: Use care during this procedure so as not to disturb or distort the cup sealing surface.**

   CAUTION: When installed, the flanged edge must be below the chamfered edge of the bore to effectively seal the bore.

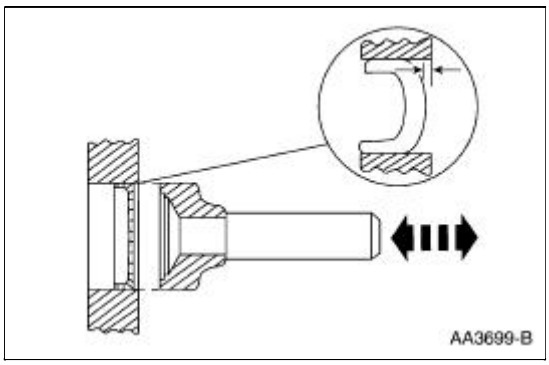
   Use a tool suitable to seat the cup-type cylinder block core plug.



Expansion-Type

1. **CAUTION: Do not contact the crown when installing an expansion-type cylinder block core plug. This could expand the plug before seating and result in leakage.**

   Use tool suitable to seat the expansion-type cylinder block core plug.

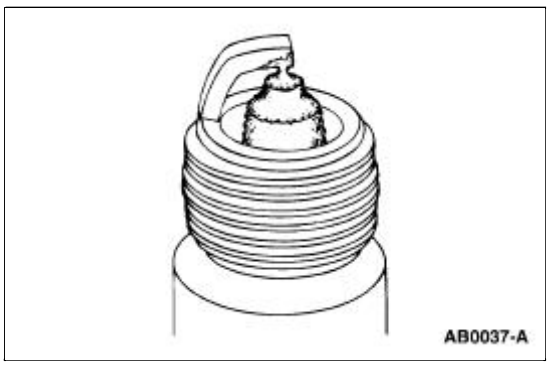


Spark Plug Hole Thread Repair

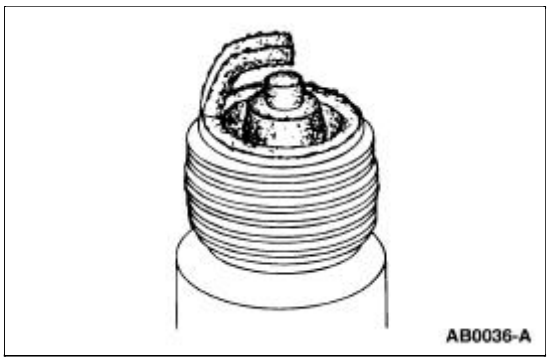
1. There is no authorized repair for spark plug hole threads. If the threads are damaged, install a new cylinder head.

Spark Plug —Inspection

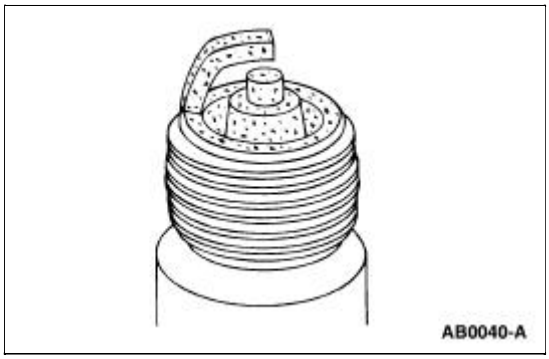
1. Inspect the spark plug for a bridged gap.
    - Check for deposit build-up closing the gap between the electrodes. Deposits are caused by oil or carbon fouling.
    - Clean the spark plug.



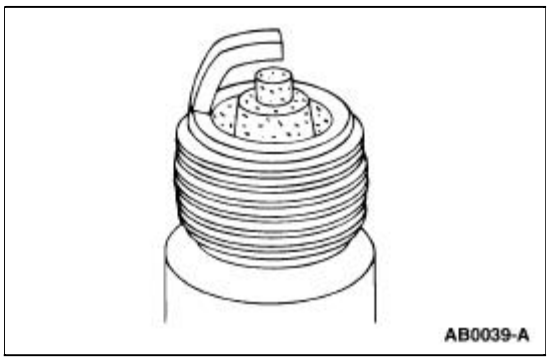
2. Check for oil fouling.
    - Check for wet, black deposits on the insulator shell bore electrodes, caused by excessive oil entering the combustion chamber through worn rings and pistons, excessive valve-to-guide clearance or worn or loose bearings.
    - Correct the oil leak concern.
    - Install a new spark plug.



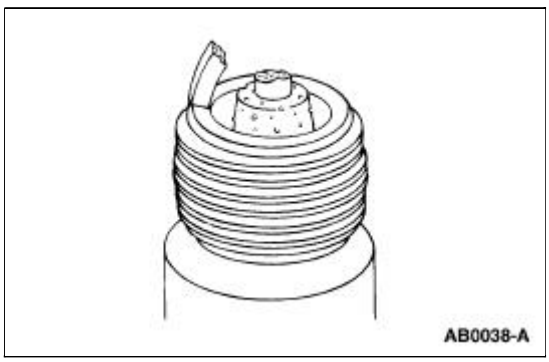
3. Inspect for carbon fouling. Look for black, dry, fluffy carbon deposits on the insulator tips, exposed shell surfaces and electrodes, caused by a spark plug with an incorrect heat range, dirty air cleaner, too rich a fuel mixture or excessive idling.
    - Clean the spark plug.



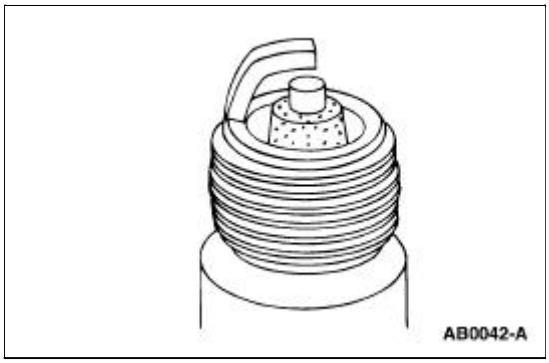
4. Inspect for normal burning.
    - Check for light tan or gray deposits on the firing tip.



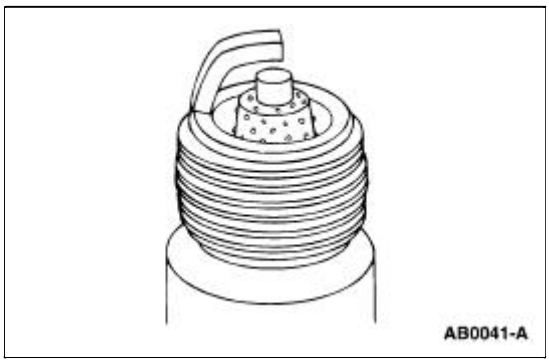
5. Inspect for pre-ignition, identified by melted electrodes and a possibly damaged insulator. Metallic deposits on the insulator indicate engine damage. This may be caused by incorrect ignition timing, wrong type of fuel or the unauthorized installation of a heli-coil insert in place of the spark plug threads.
    - Install a new spark plug.



6. Inspect for overheating, identified by a white or light gray spots and with bluish-burnt appearance of electrodes. This is caused by engine overheating, wrong type of fuel, loose spark plugs, spark plugs with an incorrect heat range, low fuel pump pressure or incorrect ignition timing.
    - Install a new spark plug.



7. Inspect for fused deposits, identified by melted or spotty deposits resembling bubbles or blisters. These are caused by sudden acceleration.
    - Clean the spark plug.

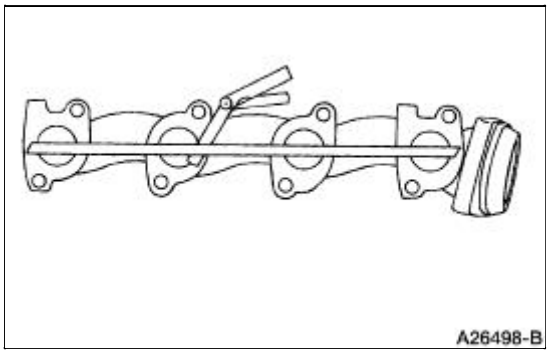


Exhaust Manifold —Inspection

Special Tool(s)

ST1246-A	Straight Edge 303-D039 (D83L-4201-A) or equivalent

1. Place a straight edge across the exhaust manifold flanges and check for warping with a feeler gauge.


A26498-B

Bearing —Inspection

1. Inspect bearings for the following defects. Possible causes are shown:
    1. Cratering — fatigue failure.
    2. Spot polishing — incorrect seating.
    3. Imbedded dirt engine oil.
    4. Scratching — dirty engine oil.
    5. Base exposed — poor lubrication.
    6. Both edges worn — journal damaged.
    7. One edge worn — journal tapered or bearing not seated.